Helminths of Ten Species of Geckos (Squamata: Gekkonidae) from Papua New Guinea, with Comparisons between Immigrant and Endemic Geckos[1]

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Abstract: Two hundred three individuals representing 10 species of gekkonid lizards from Papua New Guinea collected from 2002 to 2005 were examined for helminths: *Cyrtodactylus epiroticus* ($n = 2$), *C. klugei* ($n = 2$), *C. loriae* ($n = 7$), *C. novaeguineae* ($n = 3$), *C. sermowaiensis* ($n = 30$), *Gehyra mutilata* ($n = 22$), *G. oceanica* ($n = 27$), *Gekko vittatus* ($n = 41$), *Hemidactylus frenatus* ($n = 29$), and *Lepidodactylus lugubris* ($n = 40$). One species of Digenea, one species of Cestoda, 18 species of Nematoda, as well as three taxa of nematode larvae (in cysts) were found. Thirty-one new host records and six new locality (= country) records are reported. Prevalence in endemic geckos was significantly higher than in non-endemic geckos.

The family Gekkonidae has an almost worldwide distribution and is well represented in the Papuan Region, where 47 species have been reported (Papuan Herpetofauna 2008). The purpose of this paper is to establish an initial helminth list for the Papuan endemics *Cyrtodactylus epiroticus*, *Cyrtodactylus klugei*, *Cyrtodactylus loriae*, *Cyrtodactylus novaeguineae*, and *Cyrtodactylus sermowaiensis* and provide additional helminth occurrences for *Gehyra mutilata*, *Gehyra oceanica*, *Gekko vittatus*, *Hemidactylus frenatus*, and *Lepidodactylus lugubris*. Range maps for these host geckos in Papua New Guinea are available at http://www.bishopmuseum.org/research/pbs/papuanherps/. The last five species have previously been reported to harbor helminths (Kreis 1938, Bursey and Goldberg 1996, Goldberg and Bursey 1997, 2000*a*, 2001, Goldberg et al. 1998, 2000). Comparisons are made between helminths present in immigrant versus endemic geckos.

materials and methods

Two hundred three individuals representing 10 species of gekkonid lizards from Papua New Guinea collected from 2002 to 2005 (Appendix 1) were examined for helminths: *Cyrtodactylus epiroticus* ($n = 2$), *C. klugei* ($n = 2$), *C. loriae* ($n = 7$), *C. novaeguineae* ($n = 3$), *C. sermowaiensis* ($n = 30$), *Gehyra mutilata* ($n = 22$), *G. oceanica* ($n = 27$), *Gekko vittatus* ($n = 41$), *Hemidactylus frenatus* ($n = 29$), and *Lepidodactylus lugubris* ($n = 40$). Immediately after capture geckos were killed by an overdose of sodium pentobarbital, fixed in neutral buffered 10% formalin, stored in 70% ethanol, and accessioned in the herpetology collection of the Bishop Museum (bpbm), Honolulu, Hawai'i. Subsequently, the body cavity was opened by a longitudinal abdominal incision and the gastrointestinal tract was removed by cutting across the esophagus and the rectum, and then shipped in a vial of alcohol to Whittier College, Whittier, California, where a detailed dissection of each tract was carried out using a dissecting microscope.

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Helminths from individual hosts were removed to vials of 70% ethanol and later placed under a coverslip in a drop of lactophenol and allowed to clear. Nematodes were identified from these preparations. Digeneans and cestodes were washed in water, regressively stained in hematoxylin, and mounted in balsam for identification under a compound microscope. Although the helminths examined in this study were originally fixed in situ with formalin, each species exhibits unique characters that easily allow proper identification; no previously undescribed helminth species was found. Voucher specimens were deposited in the United States National Parasite Collection (USNPC), Beltsville, Maryland, and the Bishop Museum (BPBM), Honolulu, Hawai'i (Appendix 2). Parasite terminology is in accordance with Bush et al. (1997). Chi-square analysis, Morisita's index, and percentage similarity were used to compare infections between endemic versus nonendemic geckos (Brower et al. 1998, Magurran 2004).

RESULTS

A total of 635 helminths was collected from 69 (34%) of 205 geckos. Of these, 413 (65%) were mature individuals representing one species of Digenea (*Allopharynx macallisteri*), one species of Cestoda (*Oochoristica javaensis*), and 15 species of Nematoda (*Aplectana macintoshi*, *Maxvachonia adamsoni*, *Cosmocerca zugi*, *Maxvachonia chabaudi*, *Meteterakis crombiei*, *Moaciria chondropythonis*, *Moaciria moraveci*, *Oswaldocruzia bakeri*, *Parapharyngodon maplestoni*, *Pharyngodon novaeguineae*, *Pharyngodon oceanicus*, *Pseudorictularia dispsarilis*, *Skrjabinelazia machidai*, *Spauligodon gehyrae*, *Spauligodon hemidactylus*). *Pseudorictularia dispsarilis* occurred in the stomach; *Allopharynx macallisteri*, *Oochoristica javaensis*, and *Skrjabinelazia machidai* were found in the small intestine. All other helminths were found in the large intestines. In total 222 (35%) were immature forms (*Abbreviata* sp., *Ascarops* sp., and Acuariidae gen. sp.) represented by larvae in cysts in the stomach wall.

Although 20 species of helminths occurred in the sample, no host species harbored more than eight species (mean number of helminth species per host species was 4.1 $\pm$ 2.2; range 1–8), and no individual host harbored more than four helminth species (mean number of helminth species per infected gecko was 1.5 $\pm$ 0.8 SD; range 1–4). Of the 69 infected geckos, 46 (67%) harbored one helminth species, 15 (22%) harbored two species, 6 (9%) harbored three species, and two (3%) harbored four species. Number of individuals for each species and prevalence (number of infected hosts/number of hosts examined $\times$ 100) as well as 29 new host and six new locality (= country) records are recorded in Table 1.

DISCUSSION

The digenean *Allopharynx macallisteri* was originally described from *Lepidodactylus lugubris* collected on Guam, Mariana Islands (Dailey et al. 1998). It has also been reported from *L. lugubris* collected on Rota, Mariana Islands (Goldberg et al. 1998), and *Cyrtodactylus triparticus* (then *C. louisiadensis*) from Papua New Guinea (Bursey et al. 2005*a*).

The cestode *Oochoristica javaensis* was originally described from specimens taken from the small intestines of the geckos *Hemidactylus platyurus* (then *Cosymbotus platyurus*), *Gehyra mutilata*, and *Hemidactylus frenatus* collected in Java (Kennedy et al. 1982) and has also been reported from *Gehyra oceanica* and *Lepidodactylus paurolepis* in the Pacific realm (see Goldberg and Bursey [2002] for locality records) as well as from *Sphenomorphus jobiensis* from Papua New Guinea (Bursey et al. 2005*b*).

Six (33%) of the 18 nematodes found in this study are currently known only from Papua New Guinea (i.e., *Cosmocerca zugi*, *Maxvachonia adamsoni*, *Meteterakis crombiei*, *Moaciria chondropythonis*, *M. moraveci*, *and Pharyngodon novaeguineae*). Host lists for these species are given in Table 2. One of the 18 species, *Pseudorictularia disparilis*, is currently known only from the Australo-Papuan Region. It was originally described as *Rictularia disparilis* from specimens taken from a skink, *Pseudemoia entrecasteauxi* (formerly *Lygosoma entrecasteauxi*), collected in Australia by Irwin-Smith (1922) but reassigned to its current

TABLE 1

Number of Individuals (N), Prevalence (%), New Host Record (*), and New Locality (= Country) Record (†) for Helminths in 10 Species of Geckos from Papua New Guinea

Helminth Taxa	*Cyrtodactylus epiroticus*		*Cyrtodactylus klugei*		*Cyrtodactylus loriae*		*Cyrtodactylus sermowaiensis*		*Cyrtodactylus novaeguineae*		*Gehyra mutilata*		*Gehyra oceanica*		*Gekko vittatus*		*Hemidactylus frenatus*		*Lepidodactylus lugubris*	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Digenea																				
Allopharynx macallisteri Dailey, Goldberg & Bursey, 1998	—		—		—		—		—		—		—		*8	2	—		11	2
Cestoda																				
Oochoristica javaensis Kennedy, Killick & Beverley-Burton, 1982	—		—		—		—		—		—		—		*7	7	26	14	—	
Nematoda																				
Aplectana macintoshi (Stewart, 1914)	—		*16	100	—		*91	55	—		—		—		—		—		—	
Cosmocerca zugi Goldberg, Bursey & Kraus, 2005	—		—		—		*1	3	—		—		—		—		—		—	
Maxvachonia adamsoni Moravec & Sey, 1990	—		*1	50	—		—		—		—		—		—		—		*1	2
†*Maxvachonia chabaudi* Mawson, 1972	—		—		—		*6	10	—		—		—		4	7	—		—	
Meteterakis crombiei Bursey, Goldberg & Kraus, 2005	—		*3	100	—		*28	10	—		—		—		—		—		—	
Moaciria chondropythonis Gibbons, 1979	—		—		*1	14	—		—		—		—		—		—		—	
Moaciria moraveci Goldberg, Bursey & Kraus, 2007	—		—		—		*2	6	—		—		—		—		—		—	
Oswaldocruzia bakeri Moravec & Sey, 1986	—		—		—		—		—		—		*1	4	—		—		—	
Parapharyngodon maplestoni Chatterji, 1933	—		*2	50	—		*9	13	—		—		—		*2	2	—		—	
Pharyngodon novaeguineae Bursey, Goldberg & Kraus, 2008	*125	50	—		—		—		*26	33	—		—		—		—		—	
†*Pharyngodon oceanicus* Bursey & Goldberg, 1999	—		—		—		—		—		—		3	4	—		—		—	

TABLE 1 (continued)

Helminth Taxa	*Cyrtodactylus epiroticus* N	%	*Cyrtodactylus klugei* N	%	*Cyrtodactylus loriae* N	%	*Cyrtodactylus sermowaiensis* N	%	*Cyrtodactylus novaeguineae* N	%	*Gehyra mutilata* N	%	*Gehyra oceanica* N	%	*Gekko vittatus* N	%	*Hemidactylus frenatus* N	%	*Lepidodactylus lugubris* N	%
Pseudorictularia disparilis (Irwin-Smith, 1922)	*2	50	—		—		—		—		—		—		—		—		—	
†*Skrjabinelazia machidai* Hasegawa, 1984	—		—		—		—		—		4	18	—		—		—		—	
†*Spauligodon gehyrae* Bursey & Goldberg, 1996	—		—		—		—		—		—		5	4	—		—		—	
†*Spauligodon hemidactylus* Bursey & Goldberg, 1996	—		—		—		—		—		1	5	*1	4	—		29	34	—	
Abbreviata sp.	*4	100	*13	100	—		*60	26	*4	33	—		*3	11	*25	10	*2	3	—	
†*Ascarops* sp.	—		—		—		*93	6	—		—		—		—		—		—	
Acuariid gen. sp.	—		—		—		—		—		*2	5	*3	4	—		*12	3	—	

status by Dollfus and Desportes (1945). The host list for *P. dipsarilis* includes the frogs *Litoria inermis*, *L. nigrofrenatus*, *Rana daemeli*, and *R. supragrisea;* the lizards *Emoia caeruleocauda*, *E. kordoana*, *E. physicae*, *Pogona mitchelli*, *P. microlepidota*, and *Tiliqua occipitalis;* and the mammal *Dasyurus hallucatus* (Owen and Moorhouse 1980, Jones 1986, Bursey et al. 2008*a*, Goldberg et al. 2008). Eight of the 18 species of nematodes as well as the three genera represented by larvae in cysts have much broader distribution patterns. Hosts lists for *Aplectana macintoshi*, *Oswaldocruzia bakeri*, and *Abbreviata* sp. (larvae) are given in Bursey et al. (2008*a*); for *Maxvachonia chabaudi*, *Parapharyngodon maplestoni*, *Spauligodon gehyrae*, *Skrjabinelazia machidai*, and *Ascarops* sp. in Goldberg and Bursey (2002); for *Pharyngodon oceanicus* and *Spauligodon hemidactylus* in Goldberg et al. (2005); and for Acuariidae gen. sp. in Goldberg et al. (2008). Additions to these host lists are given in Table 1.

Eight (40%) of the 20 helminth species found in this study (i.e., *Allopharynx macallisteri*, *Oochoristica javaensis*, *Meteterakis crombiei*, *Pseudorictularia disparilis*, *Skrjabinelazia machidai*, *Abbreviata* sp., *Ascarops* sp., and acuariid larvae) require an intermediate host (Macy 1965, Conn 1985, Anderson 2000). These species were represented by 277 (44% of total) individuals and were most likely acquired by ingestion of an insect intermediate host. It should be noted that 222 (80%) of the 277 individuals requiring an intermediate host were larvae in cysts; the geckos most likely serve as paratenic hosts. The remaining 14 species, represented by 358 (56% of total) individuals, are thought to have direct life cycles (Anderson 2000). The data presented here indicate that helminth parasites (specifically those capable of reaching maturity) of Papua New Guinea geckos are largely generalists, the majority of which (357 individuals versus 55) have direct life cycles.

TABLE 2

Host Lists for Six Helminth Species Known Only from Papua New Guinea

Nematode	Type Host	Additional Hosts	Reference
Cosmocerca zugi	Gecko, *Cyrtodactylus louisiadensis*		Bursey et al. (2005*a*)
		Gecko, *Cyrtodactylus sermowaiensis*	This paper
		Skink, *Sphenomorphus jobiensis*	Bursey et al. (2005*b*)
Maxvachonia adamsoni	Hylid frog, *Litoria infrafrenata*		Moravec and Sey (1990)
		Gecko, *Cyrtodactylus klugei*	This paper
		Gecko, *Cyrtodactylus louisiadensis*	Bursey et al. (2005*a*)
		Skink, *Emoia jakati*	Goldberg et al. (2008)
		Skink, *Emoia longicauda*	Goldberg et al. (2008)
		Skink, *Emoia obscura*	Goldberg et al. (2008)
		Skink, *Emoia pallidiceps*	Goldberg et al. (2008)
		Gecko, *Lepidodactylus lugubris*	This paper
		Skink, *Sphenomorphus jobiensis*	Bursey et al. (2005*b*)
Meteterakis crombiei	Skink, *Sphenomorphus jobiensis*		Bursey et al. (2005*b*)
		Ranid frog, *Platymantis boulengeri*	Goldberg et al. (2009)
		Ranid frog, *Platymantis schmidti*	Goldberg et al. (2009)
		Gecko, *Cyrtodactylus klugei*	This paper
		Gecko, *Cyrtodactylus sermowaiensis*	This paper
		Skink, *Emoia battersbyi*	Goldberg et al. (2008)
		Skink, *Emoia obscura*	Goldberg et al. (2008)
		Skink, *Emoia pallidiceps*	Goldberg et al. (2008)
		Skink, *Emoia physicae*	Goldberg et al. (2008)
		Skink, *Emoia popei*	Goldberg et al. (2008)
		Skink, *Sphenomorphus simus*	Bursey et al. (2007*a*)
Moaciria chondropythonis	Python, *Morelia viridis*		Jones (1983)
		Gecko, *Cyrtodactylus loriae*	This paper
Moaciria moraveci	Microhylid frog, *Hylophorbus* cf. *rufescens*		Bursey et al. (2007*b*)
		Gecko, *Cyrtodactylus sermowaiensis*	This paper
Pharyngodon novaeguineae	Gecko, *Cyrtodactylus louisiadensis*		Bursey et al. (2008*b*)
		Gecko, *Cyrtodactylus epiroticus*	This paper
		Gecko, *Cyrtodactylus novaeguineae*	This paper

Five species of geckos examined in this study (*Cyrtodactylus epiroticus*, *C. klugei*, *C. loriae*, *C. novaeguineae*, and *C. sermowaiensis*), currently known only from New Guinea and the immediately adjacent islands, are represented by 45 individuals and account for 22% of the host sample. The other five species (*Gehyra mutilata*, *G. oceanica*, *Gekko vittatus*, *Hemidactylus frenatus*, and *Lepidodactylus lugubris*) are widely distributed in Oceania (Bauer and Henle 1994). Six species of helminths found in this study (*Cosmocerca zugi*, *Maxvachonia adamsoni*, *Meteterakis crombiei*, *Moaciria chondropythonis*, *M. moraveci*, and *Pharyngodon novaeguineae*), also known only from Papua New Guinea, are represented by 188 individuals and account for 30% of the helminth sample. The endemic gecko species as a group harbored 12 helminth species (Table 1). The more widely distributed gecko species as a group also harbored 12 helminth species; however, only four helminth species were common to both groups (Sorensen similarity index = 0.33). The endemic geckos as a group harbored 485 helminth individuals; 30 (67%) of 45 were infected, a mean helminth load of 16.9 per infected gecko. The wide-ranging geckos as a group harbored 150 helminth individuals; 40 (25%) of 160 were infected, a mean helminth load of 3.8 per infected gecko. The helminth loads of endemic versus nonendemic geckos are significantly higher ($\chi^2 = 35.98$, df $= 1$, $P < .001$).

Twenty taxa of helminths were found in this study. Of the helminth species known only from Papua New Guinea, only one species, *Maxvachonia adamsoni*, was found in the group of geckos of wider distribution. Thus, the wide-ranging group of geckos harbored 12 helminth species but just one individual of a helminth species known only from Papua New Guinea and 149 helminth individuals of wider distribution. Six of the 14 helminth species of wider distribution (*Aplectana macintoshi*, *Maxvachonia chabaudi*, *Parapharyngodon maplestoni*, *Pseudorictularia disparilis*, *Abbreviata* sp., and *Ascarops* sp.) were found in the endemic gecko group. Thus, the endemic gecko group harbored 12 helminth species, 185 helminth individuals of species known only from Papua New Guinea and 300 helminth individuals of species with wider distribution. Similarity indices, Morisita's index and percentage similarity, were calculated for the helminth communities harbored by endemic geckos (community A) and by the more widely ranging geckos (community B): Morisita's index = 0.184; percentage similarity = 19.3%. Morisita's index of community similarity is based upon Simpson's index of dominance (D_A and D_B) and is defined as $(2\Sigma X_i Y_i)/(D_A + D_B)(\Sigma X_i \Sigma Y_i)$, where X_i = number of individuals in taxon i in community A, Y_i = number of individuals in taxon i in community B. Percentage similarity = Σ(lower of the two percentages for each taxon). Each index ranges from 0 (no similarity) to 1 (identical) (Brower et al. 1998). Thus, there is little similarity in the composition of the helminth community in these two groups of geckos. Questions arise: Is helminth community change driven by the helminths of immigrant hosts; are immigrant hosts less susceptible to native helminths; are native hosts more quickly infected by immigrant helminths? It is well known that hosts can escape much of their native parasite community via human-assisted transport (Mitchell and Power 2003, Torchin et al. 2003, Torchin and Mitchell 2004), and *Gehyra mutilata*, *G. oceanica*, *Hemidactylus frenatus*, and *Lepidodactylus lugubris* have all been widely moved via human activities (Kraus 2009). It is unknown how recently these species arrived in the Papuan Region, but their wide and actively expanding distributions elsewhere suggest that it may have been relatively recently. Goldberg and Bursey (2000*b*) have also shown that lizards such as *Anolis sagrei* are capable of transporting helminth species from their point of origin (Caribbean) to areas they colonize (Hawai'i); but corresponding information on infections in immigrant lizards is not yet available to make conclusions about rates of helminth community change brought about by invading hosts. Nevertheless, our data are consistent with a hypothesis of infection of endemic species by helminths transported by recently immigrating hosts.

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Literature Cited

Anderson, R. C. 2000. Nematode parasites of vertebrates: Their development and transmission. 2nd ed. CABI Publishing, Wallingford, United Kingdom.

Bauer, A. M., and K. Henle. 1994. Familia Gekkonidae (Reptilia, Sauria). Part I. Australia and Oceania. Das Tierreich. Walter de Gruyter, Berlin 109:1–306.

Brower, J. E., J. H. Zar, and C. N. von Ende. 1998. Field and laboratory methods for general ecology. 4th ed. McGraw-Hill, Boston, Massachusetts.

Bursey, C. R., and S. R. Goldberg. 1996. *Spauligodon gehyrae* n. sp. (Nematoda: Pharyngodonidae) from *Gehyra oceanica* (Sauria: Gekkonidae) from Guam, Mariana Islands, Micronesia. J. Parasitol. 82:962–964.

Bursey, C. R., S. R. Goldberg, and F. Kraus. 2005*a*. New genus, new species of Cestoda (Anoplocephalidae), new species of Nematoda (Cosmocercidae) and other helminths in *Cyrtodactylus louisiadensis* (Sauria: Gekkonidae) from Papua New Guinea. J. Parasitol. 91:882–889.

———. 2005*b*. Endoparasites in *Sphenomorphus jobiensis* (Sauria: Scincidae) from Papua New Guinea with description of three new species. J. Parasitol. 91:1385–1394.

———. 2007*a*. A new species of *Falcaustra* (Nematoda, Kathlaniidae) and other nematodes from *Sphenomorphus simus* (Squamata, Scincidae) from Papua New Guinea. Acta Parasitol. 52:142–145.

———. 2007*b*. A new species of *Moaciria* (Nematoda, Heterakidae) and other helminths in the red Mawatta frog, *Hylophorbus* cf. *rufescens* (Anura, Microhylidae) from Papua New Guinea. Acta Parasitol. 52:233–237.

———. 2008*a*. A new species of *Proteocephalus* (Cestoda: Proteocephalidae), description of the male of *Desmogathiema papuensis* (Nematoda; Quimperiidae), and other endoparasites in *Sylvirana supragrisea* (Anura: Ranidae) from Papua New Guinea. Comp. Parasitol. 75:33–48.

———. 2008*b*. A new species of *Pharyngodon* (Nematoda, Pharyngodonidae) and other helminths in *Cyrtodactylus louisiadensis* (Sauria, Gekkonidae) from Papua New Guinea. Acta Parasitol. 53:41–45.

Bush, A. O., K. D. Lafferty, J. M. Lotz, and A. W. Shostak. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. J. Parasitol. 83:575–583.

Conn, D. B. 1985. Life cycle and postembryonic development of *Oochoristica anolis* (Cyclophyllidea: Linstowiidae). J. Parasitol. 71:10–16.

Dailey, M. D., S. R. Goldberg, and C. R. Bursey. 1998. *Allopharynx macallisteri* sp. n. (Trematoda: Plagiorchiidae) from the mourning gecko, *Lepidodactylus lugubris*, from Guam, Mariana Islands, Micronesia, with a key to the species of the genus *Allopharynx*. J. Helminthol. Soc. Wash. 65:16–20.

Dollfus, R. P., and C. Desportes. 1945. Sur le genre *Rictularia* Froelich 1802 (Nematodes, Spiruroidea). Ann. Parasitol. Hum. Comp. 20:6–34.

Goldberg, S. R., and C. R. Bursey. 1997. New helminth records for the mourning gecko, *Lepidodactylus lugubris* (Gekkonidae) from Hawaii. Bishop Mus. Occas. Pap., Rec. Hawaii Biol. Surv. for 1996. Part 2: Notes. 49:54–56.

———. 2000*a*. Helminth records for the house gecko, *Hemidactylus frenatus* (Gekkonidae) from Hawai'i. Bishop Mus. Occas. Pap., Rec. Hawaii Biol. Surv. for 1999. Part 2: Notes. 64:56–59.

———. 2000*b*. Transport of helminths to Hawaii via the brown anole, *Anolis sagrei* (Polychrotidae). J. Parasitol. 86:750–755.

———. 2001. Gastrointestinal helminths of gekkonid lizards (Sauria: Gekkonidae) from the Philippine Islands and Thailand. Comp. Parasitol. 68:138–142.

———. 2002. Gastrointestinal helminths of seven gekkonid lizard species (Sauria: Gekkonidae) from Oceania. J. Nat. Hist. 36:2249–2264.

Goldberg, S. R., C. R. Bursey, and H. Cheam. 1998. Gastrointestinal helminths of four gekkonid lizards, *Gehyra mutilata*, *Gehyra oceanica*, *Hemidactylus frenatus* and *Lepidodactylus lugubris* from the Mariana Islands, Micronesia. J. Parasitol. 84:1295–1298.

———. 2000. Gastrointestinal helminths of four lizard species from Moorea, French Polynesia. Comp. Parasitol. 67:118–121.

Goldberg, S. R., C. R. Bursey, and F. Kraus. 2008. Gastrointestinal helminths of eleven species of *Emoia* (Squamata: Scincidae) from Papua New Guinea. J. Nat. Hist. 42:1923–1935.

———. 2009. Endoparasites of eleven species of ranid frogs (Anura: Ranidae) from Papua New Guinea. Pac. Sci. 63:327–337.

Goldberg, S. R., C. R. Bursey, and S. R. Telford Jr. 2005. Metazoan endoparasites of four species of lizards, *Gehyra mutilata*, *Hemidactylus frenatus*, *Mabuya cumingi*, *Mabuya multifasciata* (Scincidae), and one species of snake, *Ramphotyphlops braminus* (Typhlopidae), from the Philippine Islands. Comp. Parasitol. 72:88–101.

Irwin-Smith, V. 1922. A new nematode parasite of a lizard. Proc. Linn. Soc. N. S. W. 47:311–318.

Jones, H. I. 1983. A collection of nematodes from snakes from Papua New Guinea. Syst. Parasitol. 5:131–134.

———. 1986. Gastrointestinal nematodes in the lizard genus *Pogona* Storr (Agamidae) in western Australia. Aust. J. Zool. 34:689–705.

Kennedy, M. J., L. M. Killick, and M. Beverley-Burton. 1982. *Oochoristica javaensis* n. sp. (Eucestoda: Linstowiidae) from *Gehyra mutilata* and other gekkonid lizards (Lacertilia: Gekkonidae) from Java, Indonesia. Can. J. Zool. 60:2459–2463.

Kraus, F. 2009. Alien reptiles and amphibians: A scientific compendium and analysis. Invading Nature. Vol. 4, Springer Series in Invasion Ecology. Springer Science, New York.

Kreis, H. A. 1938. Beiträge zur kenntnis paratischer nematoden. VIII. Neue parasitische nematoden aus dem Naturhistorischen Museum Basel. Zentralbl. Bakteriol. Parasitenkd. Infektionskr. 142:329–352.

Macy, R. W. 1965. On the life cycle of the trematode *Prosthogonimus cuneatus* (Rudolphi, 1809) (Plagiorchiidae) in Egypt. Trans. Am. Microsc. Soc. 84:577–580.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell Publishing, Malden, Massachusetts.

Mitchell, C. E., and A. G. Power. 2003. Release of invasive plants from fungal and viral pathogens. Nature (Lond.) 421:625–627.

Moravec, F., and O. Sey. 1990. Some nematode parasites of frogs from Papua New Guinea and Australia. Acta Soc. Zool. Bohem. 54:268–286.

Owen, L., and D. E. Moorhouse. 1980. The description of the male *Pseudorictularia disparilis* (Irwin-Smith, 1922) (Nematoda, Physalopteridae). Bull. Mus. Nat. Hist. Nat., Paris, 4th ser. 2:1013–1018.

Papuan Herpetofauna. 2008. http://www.bishopmuseum.org/research/pbs/papuanherps/lizards.html (accessed 18 November 2008).

Torchin, M. E., K. D. Lafferty, A. P. Dobson, V. J. McKenzie, and A. M. Kuris. 2003. Introduced species and their missing parasites. Nature (Lond.) 421:828–630.

Torchin, M. E., and C. F. Mitchell. 2004.

Parasites, pathogens, and invasions by plants and animals. Front. Ecol. Environ. 2:183–190.

Appendix 1

Gecko Specimens from Papua New Guinea Examined from the Herpetology Collection of the Bishop Museum (BPBM), Honolulu, Hawai'i

Cyrtodactylus epiroticus Kraus, 2008 ($n = 2$). Morobe Province: Mt. Shungol (BPBM 18653, 18654).

Cyrtodactylus klugei Kraus, 2008 ($n = 2$). Milne Bay Province: Sudest Island (BPBM 19739, 19740).

Cyrtodactylus loriae (Boulenger, 1897) ($n = 7$). Milne Bay Province: Siyomu Village, (BPBM 17255), Bunisi Village (BPBM 17256, 17257); Central Province: Fane (BPBM 18649, 18650); Morobe Province: NW slope Mt. Shungol (BPBM 18651, 18652).

Cyrtodactylus novaeguineae (Schlegel, 1837) ($n = 3$). West Sepik Province: Torricelli Mts., 2.9 to 3.2 km SSE Mt. Sapau summit (BPBM 23314–23316).

Cyrtodactylus sermowaiensis (De Rooij, 1915) ($n = 30$). West Sepik Province: Parkop (BPBM 23317–23320), 3.2 km SSE Mt. Sapau summit, Torricelli Mts. (BPBM 23321–23337, 23339–23347).

Gehyra mutilata (Wiegmann, 1834) ($n = 22$). Milne Bay Province: Pini Range, Duabo (BPBM 15435–15438), Wagabu Island (BPBM 15831), Normanby Island (BPBM 15832), Woodlark Island, Guasopa (BPBM 17708–17711), Sudest Island, Araeda (BPBM 19745–19751), Rossel Island, Damunu (BPBM 19753, 19754), Rossel Island, Cheme (BPBM 19755), Nimowa Island (BPBM 19756, 19758).

Gehyra oceanica (Lesson, 1830) ($n = 27$). East New Britain Province: Marmar (BPBM 21995), Ulege (BPBM 21996); Milne Bay Province: Wagabu Island (BPBM 15833), Fergusson Island, Basima (BPBM 15834), Misima Island (BPBM 17218–17222), Woodlark Island, Guasopa (BPBM 17712–17714), Sudest Island (BPBM 19759–19763), Rossel Island, Damunu (BPBM 19764–19769), Nimowa Island (BPBM 19970), Normanby Island (BPBM 19771); West Sepik Province: Parkop (BPBM 23348), Sibilanga (BPBM 23349).

Gekko vittatus (Houttuyn, 1782) ($n = 41$). East New Britain Province: Mamar (BPBM 21997–22001); Milne Bay Province: Misima Island (BPBM 16851–16853), Woodlark Island, Guasopa (BPBM 17700–17706), Sudest Island, Araeda (BPBM 19773–19777), Rossel Island (BPBM 19778–19784, 19786, 19787); Morobe Province: Mt. Shungol, Apele (BPBM 18656–18661); West Sepik Province: Parkop (BPBM 23350–23355).

Hemidactylus frenatus Schlegel, 1836 ($n = 29$). Central Province: Moroka (BPBM 22006); East New Britain Province: Mamar (BPBM 22002–22005); Milne Bay Province: Duabo, Pini Range (BPBM 15441), Misima Island (BPBM 16830–16833, 19788, 19789), Nimowa Island (BPBM 19790–19793), Guasopa, Woodlark Island (BPBM 17715–17722); Morobe Province: Lae (BPBM 18662), NW slope Mt. Shungol, Morobe (BPBM 18663).

Lepidodactylus lugubris (Duméril and Bibron, 1836) ($n = 41$). East New Britain Province: Mamar (BPBM 22007–22009); Milne Bay Province: Wagabu Island (BPBM 15835–15839), Gau Hi Lama Island, Killerton Islands (BPBM 15840), Misima Island (BPBM 17728, 19795–19798), Sudest Island (BPBM 19799, 19780), Rossel Island (BPBM 19801, 19802, 19804, 19805, 19807, 19808, 19810–19812, 19814–19820), Nimowa Island (BPBM 19822), Woodlark Island (BPBM 17727–17731); Morobe Province: Mt. Shungol, Apele (BPBM 18665–18668).

Appendix 2

United States National Parasite Collection (USNPC) and Bernice P. Bishop Museum (BPBM) Accession Numbers for Helminths from Gecko Specimens Collected in Papua New Guinea Examined from the Herpetology Collection of the Bishop Museum

Cyrtodactylus epiroticus: Pharyngodon novaeguineae (USNPC 101460), *Pseudorictularia disparilis* (USNPC 101461), *Abbreviata* sp. (USNPC 101462).

Cyrtodactylus klugei: Aplectana macintoshi (USNPC 101463), *Maxvachonia adamsoni* (USNPC 101464), *Meteterakis crombiei* (USNPC 101465), *Parapharyngodon maplestoni* (USNPC 101466), *Abbreviata* sp. (USNPC 101467).

Cyrtodactylus loriae: Moaciria chondropythonis (USNPC 101468).

Cyrtodactylus novaeguineae: Parapharyngodon novaeguineae (lost in processing).

Cyrtodactylus sermowaiensis: Aplectata macintoshi (USNPC 101469; BPBM H391), *Cosmocerca zugi* (USNPC 101470), *Maxvachonia chabaudi* (USNPC 101471), *Meteterakis crombiei* (USNPC 101472), *Moaciria moraveci* (USNPC 101473), *Parapharyngodon maplestoni* (USNPC 101474), *Abbreviata* sp. (USNPC 101475; BPBM H392), *Ascarops* sp. (USNPC 101476; BPBM H393).

Gehyra mutilata: Skrjabinelazia machidai (USNPC 101477; BPBM H394), *Spauligodon hemidactylus* (USNPC 101478), acuariid larvae (USNPC 101479).

Gehyra oceanica: Oswaldocruzia bakeri (USNPC 101480), *Pharyngodon oceanicus* (USNPC 101481), *Spauligodon gehyrae* (USNPC 101482), *Spauligodon hemidactylus* (USNPC 101483), *Abbreviata* sp. (USNPC 101484), acuariid larvae (USNPC 101485).

Gekko vittatus: Allopharynx macallisteri (USNPC 101486; BPBM F320), *Oochoristica javaensis* (USNPC 101487), *Maxvachonia chabaudi* (USNPC 101488; BPBM H395), *Parapharyngodon maplestoni* (USNPC 101489), *Abbreviata* sp. larva (USNPC 101490; BPBM H396).

Hemidactylus frenatus: Oochoristica javaensis (USNPC 101491; BPBM F321), *Spauligodon hemidactylus* (USNPC 101492), *Abbreviata* sp. (USNPC 101493), acuariid larvae (USNPC 101494).

Lepidodactylus lugubris: Allopharynx macallisteri (USNPC 101495; BPBM F322), *Maxvachonia adamsoni* (USNPC 101496).